Macro Economic Instability and Business Exit

Bhattacharjee, A.; Higson, C.; Holly, S.; Kattuman, P.

Publication date:
2002

Document Version
Publisher's PDF, also known as Version of record

Macro Economic Instability and Business Exit: Determinants of Failures and Acquisitions of Large UK Firms *

A.Bhattacharjee[@], C.Higson**, S.Holly*, P.Kattuman* †

March 5, 2002

Abstract

Using data over a thirty-four year span on UK quoted firms, this paper seeks to identify the factors that increase the likelihood of exit of firms. Firms may disappear through the mutually precluding events of bankruptcies and acquisitions. We use a competing-risks hazard model to determine characteristics leading to each outcome. Hazard models make use of the data on the timing of these alternative outcomes and we exploit this to focus attention on how the hazards change over the business cycle, conditional on the post-listing age of the firm. We find that the volatility in the macro environment has a role in determining, in different ways, the hazard of firms going bankrupt or being acquired.

Key words: Bankruptcy, Acquisitions, Macro-economic Instability, Competing Risks, Cox Proportional Hazards Model

JEL classification: E32, D21, C41, L16

*This work was supported by the Leverhulme Trust. We are grateful to Peter Hart, Geoff Meeks, and Melvyn Weeks for comments. Corresponding author: Paul.Kattuman@econ.cam.ac.uk

†* University of Cambridge, ** London Business School, [@] Reserve Bank of India and University of Cambridge.

1 Introduction

Corporate sectors of modern economies are engaged in a continuous programme of restructuring. Within this background process there occur dramatic restructuring episodes. Bankruptcies constitute one extreme form of restructuring. But firms at risk of going bankrupt may also find a different exit route; they may be acquired, and this may help in the efficient redeployment of their assets.[1] These extreme forms of restructuring are believed to be cyclical in nature, with bankruptcies are associated with recessions and mergers with economic recoveries.

Several studies have sought to analyse bankruptcy risk. Another stream of literature has focussed on the features that make firms takeover targets. Relatively few studies have analysed these processes within any type of unified framework to identify drivers of acquisitions and corporate failure.[2] The approach in these studies have been to determine the contribution of firm level explanatory variables such as financial performance, size, age and so on to either outcome.

While bankruptcies and mergers are both forms of exit, these will have different economic causes as well as consequences (Schary, 1991). While failing firms may avoid bankruptcy by being acquired, there are other economic motives and modalities for mergers. Firms may combine in friendly mergers that are not precipitated by distress. Firms may acquire competitors in horizontal mergers which may be hostile. Firms may also target companies for their cash flow. Determinants of a merger will depend on the motive, but information on the natures of mergers is not readily available.

There are some respects in which work to date can be enriched. First, forms of exit will not be fully determined by characteristics of firms alone. Changes in the macro economic environment works in the background and may amplify or attenuate the impacts of firm specific features on exit hazard. For example, the same macroeconomic policy can change gearing and profitability of firms differently.[3] However, the influence of variations in the

[1] Acquirers are often in related industries and may indeed have prior relationship with the target, and be informed about the value and opportunity costs of the assets.

[2] Peel and Wilson, 1989; Peel,1990; Cosh and Hughes, 1993 and recently, Wheelock and Wilson, 2000.

[3] In the research programme of which this study is a part, we have made some progress in examining some of these issues, beginning with business cycle influences on corporate

macro economic environment has not received sufficient attention in the literature; a few studies have focussed on the impact of aggregate shocks on aggregate magnitudes of firm formations and dissolutions. Caves (1998), focussing on exits of new entrants, points out: "... these studies ... control for macroeconomic conditions in various ways and degrees, but they leave the impression that ... hazard rates are rather insensitive to the observed variation in the macro environment" (pp.1958).

Secondly, little is known about the extent to which the bankruptcies and acquisitions are co-determined. Which firm-level and which macro-economic characteristics affect bankruptcy, but not acquisitions, and vice versa, and which of these codetermine both forms of exit? Also, the literature largely concentrates on exits of new firms and little work has been done on factors that affect exit probabilities of large, mature firms.

In this paper we investigate these issues using data on listed UK companies, over a long period: 1965 to 1998. We estimate a competing-risks model to consider explicitly the joint determination of the probability of being acquired and of going bankrupt; these are mutually exclusive processes (competing with each other, to restrict the survival of an operating firm). Unlike discrete outcome models, hazard models explicitly incorporate the timing of alternative outcomes, which is important when the objective is to identify the influence of macro-economic conditions on business failure.[4] We use a large set of firm level covariates along with industry level and macro variables that might affect the likelihood of it being acquired, or going bankrupt.

We focus on firms, rather than plants - bankruptcy and merger are firm-level episodes. We also focus on quoted (large and mature) firms, and on the duration of their life from the listing year. While smaller firms may be far more prone to bankruptcy, it is useful to identify driving forces that affect the large and mature firms who have substantial influence on the economy. Finally, our analysis spans several business cycles, and includes all quoted firms in existence in a relatively long period, 1965 to 1998.

---

growth and corporate profitability. See Higson, Holly and Kattuman (2002), Higson, Holly, Kattuman and Platis (2001) and Kattuman, Higson and Holly (2000).

[4] Wheelock and Wilson (2000) identify characteristics that make individual U.S. banks more likely to fail or be acquired. They estimate a competing-risks hazard model with time-varying bank-specific covariates, and find that inefficiency increases the risk of failure while reducing the probability of a bank's being acquired. Lower equity-to-assets ratio, reflecting insolvency probability, makes acquisition more likely.

The econometric analysis incorporates some innovations. Taking the cue from recent work on the econometrics of duration models, we explore whether exit drivers affect firms of different ages (from listing) differently. To accommodate the violation of the proportional hazards assumption, we allow time-varying coefficients in the Cox proportional hazards model. Secondly, by modelling exits due to bankruptcies and acquisitions explicitly, the estimation method is made robust to dependence between these competing causes of exit. Third, given that (dependent) left-truncation may introduce bias in the estimates of the duration models of firm exit, we test the independence of truncation and exit durations, and explore robustness of our results with respect to violations of such independence.

The next section reviews the literature. Section 3 describes the data. Section 4 describes hazard models of bankruptcy and acquisitions in a competing risks framework. Section 5 presents the results of the hazard estimation, while Section 6 explores robustness of our results to the presence of dependent left-truncation. We collect conclusions in Section 7.

2 Literature

The main theoretical models of the firm life-cycle that analyse stochastic processes determining the growth and failure of firms are well known; however, these models do not consider acquisition.

"Passive learning" formulations (Jovanovic, 1982; see also Hopenhayn, 1992; and Cabral, 1993) model firms as entering uncertain of their capability, and then receiving repeated noisy signals of their capability, which induce them to expand, contract, or exit. The model predicts that exit hazard declines with firm age though not necessarily from the outset. Low capability firms learn only from experience about their poor fitness. Empirical evidence in favour of the model includes Evans (1987) and Dunne *et. al.* (1989) on US firms. In the "active learning" formulation (Nelson and Winter, 1978; Ericson and Pakes, 1992, 1995; Pakes and Ericson, 1998) firms invest in uncertain but expectedly profitable innovations, and grow if successful, shrink or exit if unsuccessful.[5]

[5] Plants descend through the productivity ranking with age until refurbished or retired. Passive learning model fit retailing sector better, while active learning may be more appropriate for the manufacturing sector (Pakes and Ericson, 1998).

Cooley and Quadrini (1999) present a general equilibrium model of firms reacting to financial drivers and show how financial factors affect firm survival through the internal finance channel, and why the response of small firms might be larger.[6] Delli Gatti *et. al.* (2000, 2001) also present a theoretical model linking the macro-economic environment, financial fragility and entry and exit of firms. These models await empirical support.[7]

2.1 Stylised Facts about Exits[8]

A large body of empirical work have collected several stylised facts about exit. Several studies have noted that entry and exit rates are highly correlated (Schwalbach, 1991, across several countries; Dunne *et. al.*, 1989; and Dunne and Roberts, 1991, for the US; and Geroski, 1991a, 1991b, for the UK), though the nature of the relationship between the two differ across industries (Agarwal and Gort, 1996), as well as over the ascending and descending stages of the business cycle (Boeri and Bellman, 1995; Sleuwaegen and Dehandschutter, 1991; Baldwin and Johnson, 1996; and Mata *et. al.*, 1995).

Exit rates decline with firm age (Dunne *et. al.*, 1989 and Audretsch, 1991, for the US; Baldwin, 1995, in Canada; Mata *et. al.*, 1995, in Portugal; and Disney *et. al.*, 2000, for the UK), consistent with theoretical models of learning.

Over the business cycle, exit rates increase during the downturn (Caballero and Hammour, 1994, 1996; and Audretsch and Mahmood, 1995). Growth rates and exits both vary with size and financial stability ("life cycle hypothesis") (Fazzari *et. al.*, 1988; Klepper, 1996), and nominal and real shocks (Judd and Treham, 1995).

Firm-level factors, such as size (and start-up size) (Dunne *et. al.*, 1989; Mata *et. al.*, 1995; and Caves, 1998) and financial fragility (Fazzari *et. al.*,

[6]Their simulation exercise suggests that financial factors do not affect aggregate economy in a large way, though they may cause volatility in financial markets, particularly stock markets.

[7]Among other models, Corres and Ioannides (1996) present a model that allows for three kinds of exits - bankruptcy, (endogenous) exits when the current value of expected profit stream falls below a threshold (voluntary liquidation), and (exogenous) exits caused by macro-economic shocks. See also Abowd *et. al.* (1995).

[8]See also reviews by Siegfried and Evans (1994) and Caves (1998).

1988; Klepper, 1996; Cooley and Quadrini, 1998, 1999; Delli Gatti *et. al.*, 2000, 2001) are significant for firm exits. The impact of firm-level efficiency (Audretsch and Mahmood, 1991), productivity (Winter, 1999; Doms *et. al.*, 1995) and profitability (Schary, 1991; Corres and Ioannides, 1996) on business failure have also been explored. Industry characteristics, such as technology orientation (Mahmood, 1992) and presence of MNCs (technology transfers) (Gőrg and Strobl, 2000) have significant impact on exit rates, while market growth and R&D intensity appears to have relatively negligible effect (Mahmood, 1992).

Some empirical studies on exits in the UK are relevant to our analysis. Disney *et. al.* (2000) examined the UK establishment (ARD) database for the period 1986-1991, and estimated a hazard model of new firm survival. About 65 per cent of new entrants exited within five years; approximately half these were takeovers by other companies under the same ownership groups. They note that exit and entry rates correlate strongly, both across time and within industries. Their estimates indicate the importance of learning (exit rates decline with age).[9]

At the firm level, Goudie and Meeks (1991, 1992, 1998) have explored the role of macroeconomic factors in corporate failure by tracing the probable effects of exogenous macro shocks upon the finances and viability of individual companies by simulating their financial statements, contingent on macroeconomic developments. They found significant asymmetric and non-linear impact of the exchange rate upon the failure rates of U.K. companies. Through retrospective analysis of macro shocks they show how for a notable minority among the major failing corporations, the shock determined their collapse.

Empirical macro-studies relating the macroeconomic environment to business performance in the UK have noted that movements in the aggregate failure rate of business establishments have coincided with changes in macroeconomic performance (Hudson, 1986; Department of Trade and Industry, 1989). With a more specific focus, Desai and Montes (1982) have explored the effect of changes in the interest rate and growth of money stock upon the aggregate failure rate. Using aggregate measures, Black *et. al.* (1996) and Robson (1996) have studied the impact of macro environment on firm

[9]Harris and Hassaszadeh (2000) have used the same database, but confined their study to a single industry (motor vehicles).

dissolutions in the UK. With the notable exception of Goudie and Meeks (1991, 1992, 1998), none of the above studies have explicitly analysed the micro-evidence for the impact of macroeconomic conditions.

3 Data

Evaluation of the impact of macro-economic fluctuations on exits requires data spanning several business cycles. We use a company-level database constructed by combining the Cambridge- DTI, DATASTREAM and EXSTAT databases of company accounts. The combined company level accounting data provides an unbalanced panel of about 4300 UK listed companies over the period 1965 to 1998. There were 166 instances of bankruptcy and 1859 acquisitions in around 49000 company years over the 34 year period.[10] In terms of hazard model analysis, the data are right-censored and left-truncated.[11]

These data were augmented by several annual indicators of macro- economic conditions and instability. Most of the covariates used to explain exit probablities/ hazard rates are, thus, essentially time-varying covariates. Following Chadha *et. al.* (2000), business cycle (BC_t) was measured by an HP-filtered series of UK output per capita ($\lambda = 100$). Annual growth rate in the number of companies registered in the UK during each year (in percentage terms) is our indicator of business entries. Real interest rates were measured as the yield on 20-year sovereign bonds, minus the annual rate of inflation. The average annual GBP/USD exchange rate was used to measure the exchange rate environment.

Figure 1 plots, year-wise, the incidence of bankruptcies[12] and the business

[10] A firm that has irretrievably entered the path to bankruptcy may in a precursor phase of distress stop publishing accounts one or two years prior to actually being declared bankrupt. From the point of view of econometrically modelling bankruptcy it is sensible to reassign the date of bankruptcy to the year of last published accounts when the firm has been declared bankrupt within a 2 year period. This implies that our assignment of a bankruptcy to a particular point in time may be characterised as the time period when the "real" economic bankruptcy takes place, rather than the year when the firm is actually declared bankrupt.

[11] For each company ever listed over the period of analysis, the data used for the analysis pertain to years, since 1965, during which the company is listed in the London Stock Exchange. Hence, for each company, the available data are left-truncated, and do not pertain to the entire period that it is listed.

[12] Incidence is defined as the ratio of the number of companies that went bankrupt

cycle indicator for the year. Quoted company bankruptcies were particularly high during years when the economy turned down after a peak, and were lower during upturns in the business cycle. The growth rates in company registration (Figure 2) provide some *a priori* rationalisation for this; entries are pro-cyclical and it may be hypothesized that the larger number of entries during the upturn of the business cycle may force some firms out of business when the economy turns down. Figure 3 indicates that acquisitions were procyclical.

Figures 1, 2 and 3 suggest, a-priori, the importance of stability in the macroeconomic environment for the survival of even mature firms. The measure of macroeconomic instability we include is intended to capture the sharpness of the economic turnaround; we use the increment of the change in business cycle in the current year $(BC_t - BC_{t-1})$ from that in the previous year $(BC_{t-1} - BC_{t-2})$.[13] We measure uncertainty in the foreign exchange markets by the year-on-year change in the GBP/USD exchange rate.[14] Uncertainty in prices, and long-and short-term interest rates are measured by the largest month-to-month rate of change within the year, of retail price index, yield rates on 20-year sovereign bonds, and 91-day T-bill rates respectively.

Descriptive statistics are given in Table 1. These include industry dummies and firm-level variables (size[15], ratio of cash flow to capital[16] and return on capital[17]) and measures of macroeconomic conditions and instability dis-

---

during the year, to the total number of listed companies in the year. The incidence for acquisitions was defined similarly.

[13]This, in year t, is, thus, $[BC_t - BC_{t-1}] - [BC_{t-1} - BC_{t-2}]$. Over a business cycle, this would be lowest right after the peak, when the economy turns around downwards, and continue to increase gradually upto its maximum right after the trough, when the economy picks up. Over different business cycles, this measure would be lower (or higher) for a cycle in which the economy turns down sharply after a sharp upturn (or turns up sharply after a sharp downturn).

[14]Goudie and Meeks (1991) suggest that a weaker pound sterling helps maintains export competitiveness of UK industry, and is more conducive to the survival of firms. It may be argued that a sharp depreciation in the pound sterling may not, however, be advantageous to domestic business. Our construction of this uncertainty measure is aimed at testing this hypothesis.

[15]Size is measured as the logarithm of fixed capital (in real terms), incremented by unity.

[16]Cash flow is measured as the total of operating profits and depreciation, net of taxes (excluding taxes on non- operating income, but including taxes saved on interest payments). Cash flow to capital ratio is the ratio of cash flow to total assets.

[17]Ratio of post-tax profits to capital employed

cussed above. The sample characteristics display significant variability both across firms, and over the 34 year period.

TABLE 1: Sample characteristics of the explanatory variables

Variables	N	Mean	Std.Dev.	Min.	Max.
INDUSTRY DUMMIES					
Food/ Breweries	45546	0.072	0.26	0	1
Chem./Pharma.	45546	0.063	0.24	0	1
Engineering	45546	0.123	0.33	0	1
Electronics	45546	0.066	0.25	0	1
Textiles	45546	0.117	0.32	0	1
Bldg.products	45546	0.054	0.23	0	1
Media	45546	0.044	0.21	0	1
Construction	45546	0.063	0.24	0	1
Trdg./Superstores	45546	0.117	0.32	0	1
Hotels/Entertainment	45546	0.105	0.31	0	1
FIRM $\times$ YEAR LEVEL					
Size: ln(rl.fixed capl. + 1)	45546	4.607	1.83	0	12.9
Cash flow to Capital	45546	0.079	0.28	-45.6	7.3
Return on Capital employed	45546	0.165	6.56	-461.0	593.5
MACRO- CONDITIONS					
Business cycle	34	0.0018	0.024	-0.040	0.048
Entries (y-o-y growth rate)	34	6.87	16.4	-38.5	54.8
Long-term real interest rate	34	2.515	3.50	-9.8	6.4
$\pounds - \$$ exchange rate	34	0.535	0.12	0.36	0.77
MACRO- INSTABILITY					
Turnaround in business cycle	34	0.0000	0.025	-0.084	0.047
Increase in exchange rate	34	0.0072	0.049	-0.089	0.104
Volatility - RPI	34	4.255	2.53	0.36	10.80
Vol. - Long term int.rate	34	0.112	1.79	-3.8	4.0
Vol. - Short term int.rate	34	0.296	3.37	-8.2	5.8

4 The Econometric Methodology

While most empirical studies on firm exits have used hazard models for inference, some have been based on discrete outcome or scoring models (probit, logit etc.).[18] Unlike the latter, hazard models explicitly incorporate the timing of alternative outcomes. They segregate the age aspect of the propensity to survive (or exit) from the effect of other covariates. This is important for our objective of disentangling the influence of macroeconomic conditions on business exit from those of firm-specific and industry factors.

The risk of bankruptcy and acquisitions is modelled in a unified framework. Each firm is conceived as being concurrently under risk of bankruptcy and acquisition during each year over its lifetime. Bankruptcy and acquisitions may be thought of as mutually exclusive outcomes (governed by their own underlying driving processes) competing to restrict the survival of an operating firm. Under a hazard model framework, this data generating process can be suitably parametrised using a competing risk model.

4.1 Competing Risks Framework

The competing risks framework has become popular for analysis of concurrent risks of failure in different application areas and has acquired a substantial statistical/ econometric literature. Aalen (1982) provided estimates of cause-specific intensity (hazard)rates $\lambda_h(t;\theta)$, where

$$\lambda_h(t;\theta) = \lim_{\epsilon \succ 0} \frac{1}{\epsilon} P[T < t + \epsilon; H = h | t \geq t; \theta]$$

where $H = 1, ...k$ are the k competing causes of failure, and $\lambda_h(0;\theta) = 0; h = 1, ...k$.

This is equivalent to considering independent random variables $X_{i1}, ..., X_{ik}, i = 1, ...n$ with hazard functions $\lambda_1(t;\theta), ..., \lambda_k(t;\theta)$ and the multivariate counting process $N(t) = (N_1(t), ..., N_k(t))$ with $N_h(t) = \sum_{i=1}^{n} I\left(min_{l=1,...k} X_{il} = X_{ih} \leq t\right)$. The X_{ih}'s are independent "latent" (or "underlying") failure times.

The Cox Proportional Hazards (PH) model (Cox, 1972) can then be used as a convenient model for the cause-specific hazard rates corresponding to the competing causes of failure. The Cox PH model for competing risks postulates that the logarithm of the cause-specific hazard function is a linear function of the covariates (explanatory variables), or equivalently

[18] Multinomial probit/ logit models have been used by Corres and Ioannides (1996) for analysis of competing causes of exit for US quoted companies. They also use a hazard model in their empirical work, but do not segregate the hazard processes owing to different causes of failure.

$$\lambda_h(t;\theta) = \lambda_{0h}(t).\exp\left[\underline{\theta_h}'\underline{z}\right]$$

where $H = 1, ...k$ are the k competing causes of failure, $\lambda_{0h}(t)$ are the baseline hazard functions correponding to the h-th cause of failure[19] at time t, $\underline{z}$ is the vector of covariates, and $\underline{\theta_h}$ are the vectors of coefficients corresponding to the h-th cause of failure.[20]

When interest focuses on failures from one specific cause[21], it is usual to consider failures due to other causes as right-censoring of the data. If independent latent failure times are assumed, for any "cause-specific" hazard rate one may consider failures from other causes as independent censoring (Andersen *et. al.*, 1992, pp.144). This leads to a simple random censorship model. However, this assumption is questionable. Departures from the assumption of independence often leads to non-identifiability of competing risks, or lack of efficiency in inference.

But Cox (1962) and Tsiatis (1975) show that for any joint distribution of latent failure times, there exists a joint distribution with independent failure times which gives the same distribution of the identified minimum. Heckman and Honoré (1989) established identifiability of the competing risk model with marginal hazard functions following the Cox PH model, under very general dependence structures. Here identifiability is established through the inclusion of time-invariant covariates (with constant regression coefficients). Han and Hausman (1990) establish alternative identifiability conditions under unobserved heterogeneity conditions, and McCall (1994) extends the identifiability results to the situation where the regression coefficient of a covariate is allowed to vary over time.[22] Thus identifiability may be extended to wider classes of models if time-varying covariates are introduced.

Even though identifiability is established, inference under the model is in general inefficient if hazards due to the different causes of failure are not independent. However, efficient estimates can be derived if the cause-specific

[19]In our case, h is bankruptcy or acquisition

[20]Note that, under the model, the impact of a covariate on the hazard of different causes of failure would, in general, be different. Some of them may even be zero. This is, thus, a flexible regression framework for the study of the impact of various covariates on the hazards of failure due to competing causes.

[21]like, in our case, either bankruptcies or acquisitions

[22]van den Berg (2000) provides an elaborate review of the literature.

hazard function of interest is independent of the censoring, conditional on an adequate selection of covariates. In fact, if the conditional censoring becomes noninformative about the conditional cause-specific hazard of interest (in an appropriate sense, see Andersen *et. al.*, 1992, pp.150-151; Arjas and Haara, 1984) the usual partial likelihood inference is efficient. In essence, if censoring depends on time-invariant covariates which are not included in the model for the cause-specific hazard, inference is inefficient. If, however, the same covariates are included in the cause-specific hazard and censoring mechanisms, efficient partial likelihood estimates can be derived (after specifically taking care to include these covariates also in the hazard model) by assuming that censoring is independent of the cause-specific hazard, conditional on covariates.

In this study, the competing risks framework involves estimation of two separate Cox PH models, one for exits due to bankruptcy and one for acquisitions. In each case we treat exits due to the other cause as censored cases, in addition to observations originally censored (due to delisting and other reasons). In the model for bankruptcy, we include all covariates that affect the hazard of exits due to acquisition, and vice versa, and conditional on the covariates, the exits due to either of the two competing causes are assumed to be independent of censoring due to the other.[23] Thus, the explicit estimation of separate models for the two major competing causes of exit allows us to take care of dependence between these two different modes of exit.

4.2 Left-truncation

In addition to right-censoring (by dependant competing risks), duration data we analyse are truncated to the left; they pertain only to the period after 1965. The left-truncation duration is given by $L = \max(L^{**}, 1965 - B)$, where B is the listing-year of the company, and L^{**} represents any delay in entry into the panel subsequent to listing. If this left-truncation is conditionally independent of the failure process given the covariates, the Cox partial likelihood estimates based on a modified definition of risk sets (delayed entry)

[23] In essense, we assume the absence of significant unobserved heterogeneity, or frailty. Having included in our analysis a wide variety of firm-, industry- and economy-level covariates, we feel justified in believing that these covariates together would encompass any information relevant to exits due to bankruptcy and acquisitions, apart from random variations.

would be consistent (Cnaan and Ryan, 1989; Keiding, 1997).

To see this, consider the random (left-)truncation model (Woodroofe, 1985; Wang *et. al.*, 1986; Keiding and Gill, 1990) with right censoring, given by n independent replications $(L_1^*, T_1^*, \delta_1^*, \underline{Z}_1^*), \ldots, (L_n^*, T_n^*, \delta_n^*, \underline{Z}_n^*)$ from the conditional distribution of (L, T) given $L < T$, where T are right-censored durations, δ are indicators reflecting that the unit is not censored, and $\underline{Z}$ are (possibly time-dependant) covariates. Then, if L and T are conditionally independent, given $\underline{Z}$, one can write, in simplified notation:

$$\frac{P\{T = t | L = l, \underline{Z} = \underline{z}, T > L\}}{P\{T \geq t | L = l, \underline{Z} = \underline{z}, T > L\}} = \frac{P\{T = t | \underline{Z} = \underline{z}\}}{P\{T \geq t | \underline{Z} = \underline{z}\}}.$$

Let $t_{(1)} < t_{(2)} < \ldots < t_{(r)}$ be the r distinct observed failure times, and assume for the moment that there are no ties (*i.e.*, $n-r$ censored durations). Let $R\left(t_{(i)}\right)$ denote the risk set at $t_{(i)}$. That is, $R\left(t_{(i)}\right)$ includes the units that have entered the study by $t_{(i)}$, and have not exited and have not been censored by the duration $t_{(i)}$. Then, following Cnaan and Ryan (1989) and Keiding and Knuiman (1990), one can write the partial likelihood of β, under the Cox proportional hazards model as:

$$L = \prod_{i=1}^{r} \frac{\exp\left[\underline{\beta}' \, \underline{z}_{(i)}\left(t_{(i)}\right)\right]}{\sum_{j \in R\left(t_{(i)}\right)} \exp\left[\underline{\beta}' \, \underline{z}_j\left(t_{(i)}\right)\right]}$$

where $\underline{z}_{(i)}\left(t_{(i)}\right)$ is the vector of (time-dependant) covariates of the unit exiting at $t_{(i)}$ evaluated at the duration $t_{(i)}$, and $\underline{z}_j\left(t_{(i)}\right)$ is the vector of covariates of the unit j belonging to the risk set $R\left(t_{(i)}\right)$ evaluated at the duration $t_{(i)}$. Here, tied exit durations can be handled in the usual way (see Andersen and Gill, 1982). The only difference between this partial likelihood and the usual partial likelihood under the Cox PH model is in the definition of the risk set $R\left(t_{(i)}\right)$. While the usual risk set includes all units that have not exited and have not been censored by the duration $t_{(i)}$, the risk set here includes only those units, that have entered the frame by $t_{(i)}$.[24] The properties of the

[24]For example, if $(0,1,1), (2,8,1), (0,5,0)$ is a triad of observations on (L, T, δ), then only the units 1 and 3 would belong to the risk set at exit duration 1. If observation 2 were not truncated, *i.e.* if observation 2 were $(0,8,1)$, then it would also have belonged to the risk set at duration 1. This shows how inference can be derived under the Cox PH model with left-truncated data by modeling the truncation as delayed entry (*i.e.*, by modifying the risk set) (see also Keiding, 1992, 1998).

maximum partial likelihood estimator $\hat{\beta}$ has been discussed elsewhere (Tsai and van Ryzin, 1985). As expected, the standard errors of these estimates will be higher than those for data that are not truncated.

Tsai(1990) provides an unconditional test for the independence between truncation and (censored) exit duration that can be employed in any application. However, though the partial likelihood estimates would be valid even if truncation and exit durations are independent only conditional on covariates, the independence assumption cannot be tested.[25] The impact of dependence on the estimates can be examined with standard analysis, by including truncation time as a stratification factor (Cnaan and Ryan, 1989). In Section 6, we explore the issues relating to independent left-truncation and evaluate the robustness of results to dependence. Specifically, we estimate our exit duration models conditioned on different ranges of the truncation duration and compare estimates for similarity.[26]

4.3 Violation of Proportionality and Time-Varying Coefficients

The Cox PH model substantially restricts interdependence between the explanatory variables and duration - the coefficients of the hazard function regressors are restricted to be constant over time. This may not hold in many situations, or may even be unreasonable from the point of view of relevant economic theory (McCall, 1994). In particular, the effect of a covariate on the hazard is often observed to be increasing or decreasing in age (sometimes over the whole covariate space, and sometimes over a range of the covariate space). This clearly constitutes a violation of the proportionality assumption.[27]

An appealing solution to such violation of proportionality is to allow the

[25] As shown in Keiding (1992), independence would not be valid if there is unobserved heterogeneity (*i.e.*, truncation and exit durations depend on a common underlying frailty).

[26] An alternative test of conditional independence would be to include the truncation duration as a covariate in the Cox regression model, and verfiying that it has no significant effect on the hazard (Bull and Spiegelhalter, 1997). The underlying assumption, under this approach, that the impact of truncation duration on the hazard is in the nature of a Cox PH model is, however, arbitrary.

[27] Some applications where such violations of the PH model is evident and tests of the PH model against such alternatives is presented in Bhattacharjee and Das (2001).

covariate to have different effects on the hazard according to age of the firm. Several estimators have been proposed in the literature (see, for example, Zucker and Karr, 1990; Murphy and Sen, 1991; Martinussen *et. al.*, 2000) that allow for such time-varying coefficients in the Cox regression model. In this paper, we have used the appealing histogram-sieve estimators of Murphy and Sen (1991), based on the method of sieves (Grenander, 1981), which we find intuitively appealing and amenable to useful inference. This method entails dividing the duration axis into several intervals and including the continuous covariate multiplied by an indicator function that reflects each of the intervals as covariates in a modified Cox PH model. In the analysis that follows, the lives of firms, post-listing, was divided into four intervals (0-5 years, 6-15 years, 16-25 years, and greater than 25 years). As our results will demonstrate, this helps us to effectively characterise the way the impact of a covariate varies over the life of the firm.

5 Results

The maximum partial likelihood model estimates (Kalbfleisch and Prentice, 1980) of the two models (for bankruptcies and acquisitions) are reported in Table 2. The reported z-scores are based on robust standard error estimates proposed by Lin and Wei (1989) for regression coefficients in the Cox proportional hazards model. The fit of models is judged using the goodness-of-fit test by Grambsch and Therneau (1994) based on adjusted Schoenfeld residuals (Schoenfeld, 1982); the models are satisfactory.

TABLE 2: Model Estimates

Variables	**Bankruptcy**	**Acquisitions**
INDUSTRY DUMMIES		
(Base = all others)	1.00	1.00
– Food/Breweries	0.5112 (-1.1)	1.1524 (1.4)
– Chem./Pharma.	1.0529 (0.1)	1.1765 (1.6)
– Engineering	2.2132 (2.5)*	1.0940 (1.1)
– Electronics	0.7099 (-0.7)	1.4532 (4.1)**
– Textiles	2.8669 (3.5)**	1.0392 (0.4)
– Bldg. products	0.4024 (-1.2)	1.1374 (1.2)
– Media	1.9360 (1.6)	0.9515 (-0.4)
– Construction	3.2630 (3.7)**	0.8643 (-1.2)

TABLE 2: Contd.

Variables	Bankruptcy	Acquisitions
– Trading/Superstores	1.6619 (1.5)	1.1157 (1.3)
– Hotels/Entertainment	1.5287 (1.3)	0.9911 (-0.1)
FIRM × YEAR LEVEL		
Current size:		
ln(real fixed capital +1)	1.4871 (1.6)	1.4116 (5.3)**
Size-squared	0.9421 (-2.2)*	0.9613 (-6.2)**
Cash flow to Capital $= x$		
– $x\times$ I(age 0-5 yrs.)	0.9081 (-3.3)**	4.1786 (4.4)**
– $x\times$ I(age 6-15 yrs.)	0.6821 (-4.0)**	1.3017 (2.5)*
– $x\times$ I(age 16-25 yrs)	0.1132 (-1.6)	0.3508 (-2.8)**
– $x\times$ I(age $>$ 25 yrs)	0.3807 (-3.3)**	0.6607 (-2.0)*
Return on Capital employed	0.9965 (-2.2)*	1.0010 (0.9)
MACRO-ECONOMIC CONDITIONS		
Business cycle $= y$		
– $y\times$ I(age 0-5 yrs.)	34901.3 (1.4)	75130.5 (4.2)**
– $y\times$ I(age 6-15 yrs.)	0.0024 (-0.7)	1734.18 (3.2)**
– $y\times$ I(age 16-25 yrs)	2.91e-5 (-1.1)	0.0434 (-1.0)
– $y\times$ I(age $>$ 25 yrs)	4716.04 (1.2)	28.5348 (1.2)
Entries (y-o-y growth rate)	1.0140 (1.7)$^{+}$	0.9969 (-1.7)$^{+}$
Long-term real interest rate $= r$		
– $r\times$ I(age 0-5 yrs.)	1.1625 (1.4)	1.1210 (3.6)**
– $r\times$ I(age 6-15 yrs.)	1.0179 (0.4)	0.9451 (-4.0)**
– $r\times$ I(age 16-25 yrs)	0.9620 (-0.9)	0.9936 (-0.3)
– $r\times$ I(age $>$ 25 yrs)	1.0718 (0.9)	0.9731 (-1.4)
$£-\$$ exchange rate	0.0804 (-1.9)$^{+}$	7.0479 (5.2)**
MACRO-ECONOMIC INSTABILITY		
Turnaround in Bus. cycle $= u$		
– $u\times$ I(age 0-5 yrs.)	9.26e-11 (-3.0)**	0.0170 (-1.7)$^{+}$
– $u\times$ I(age 6-15 yrs.)	0.1523 (-0.3)	300.334 (2.6)**
– $u\times$ I(age 16-25 yrs)	0.0005 (-1.0)	19.7929 (1.4)
– $u\times$ I(age $>$ 25 yrs)	0.0002 (-1.0)	1.8340 (0.2)
y-o-y increase in $£-\$$ exchange rate $= v$		
– $v\times$ I(age 0-5 yrs.)	9.60e+5 (3.5)**	0.4241 (-0.7)
– $v\times$ I(age 6-15 yrs.)	289.4563 (1.4)	0.3219 (-1.1)
– $v\times$ I(age 16-25 yrs)	17.5767 (0.5)	0.0720 (-1.8)$^{+}$
– $v\times$ I(age $>$ 25 yrs)	1305.16 (1.7)$^{+}$	1.0367 (0.0)

TABLE 2: Contd.

Variables	Bankruptcy	Acquisitions
Volatility - Retail price index	1.2759 (5.8)**	0.9040 (-5.9)**
Volatility - Long term int. rate	0.9869 (-0.2)	1.0326 (1.7)+
Volatility - Short term int. rate	0.9495 (-1.4)	0.9915 (-0.8)
No. of firms	4,320	4,320
No. of exits	166	1,859
Total time at risk (in years)	45,527	45,527
Log-likelihood	-1090.592	-12947.057
Chi-square test stat.(PH assmp.)	29.99	14.36
d.f. / p-value	38 / 82.0	38 / 100.0

z-scores in parentheses.

Parameters reported are hazard ratios (exponential of the actual parameter values).

Volatility is measured as maximum monthly difference during the year, divided by the number of intervening months (signed).

**, * and + – Significant at 1%, 5% and 10% level respectively.

Overall we see significant impact of industry characteristics, firm-level characteristics, macroeconomic conditions and macroeconomic instability on exits in either form. Overall, construction, textiles and engineering companies are more likely to go bankrupt, while companies in the electronics industry are more likely to be acquired.

There is evidence that cash flow and profitability reduces the hazard rate of bankruptcy. The effect of cash flow on acquisition varies with the post listing age of the firm. Recently listed firms with higher cash flow are more likely to be acquired, unlike older cash-rich firms.[28] The rates of bankruptcy and acquisition decline with size, sharply in the higher size-ranges. Figure 4 shows the estimated hazard ratios against size-percentiles after conditioning on other covariates. There is a sharp decline of bankruptcy hazard with size. The figure also reinforces the stylised fact that quoted firms in the middle range of the size-distribution are considerably more likely to be acquired.

Periods of robust economic activity significantly heighten acquisition probabilities of firms that have recently been listed; this is not true of companies

[28]This is one peice of evidence of non-proportionality of hazards with respect to cash flow. This also underscores the advantage of the Murphy-Sen histogram sieve estimators in deriving credible inference in such non-proportional situations. For a more detailed discussion of the issue, see Bhattacharjee and Das (2001).

that have been listed for a while. The business cycle does not have much of a direct impact on bankruptcy hazard; however, higher entry rates increase it and a stronger currency depresses it somewhat. Such periods also see higher acquisition hazards. Firms that have been recently listed are more likely to be acquired during periods of higher long-term real rates of interest, unlike older firms.

The impact of macroeconomic instability on business exits is substantial. We have noted the higher propensity of firms to go bankrupt when the economy enters a downturn (Figure 2). Results in Table 2 reflect that this higher hazard of bankruptcy is largely confined to firms that have been listed recently (within the previous 5 years). Evidently, these firms had been listed during the upturn of the business cycle, and they are the quickest to go bankrupt when the economy turns down. Firms listed 6-15 years previously are most likely to be acquired immediately after the economy crosses the trough. It could be that firms that have weathered the downturn increase in value as takeover targets.

Newly listed companies are more likely to go bankrupt during years when the pound sterling depreciates sharply. This contrasts somewhat with the evidence that a weaker currency (in level) aids survival, and reflect the detrimental impact of macro instability (uncertainty) on firm survival. The fact that volatility in prices increases bankruptcy and subdues M&A activity lends further support to this interpretation.

Figure 5 shows a plot of the baseline cumulative hazard functions of bankruptcy and merger against the age of the firm reckoned from listing date. Note that the hazard of mergers is over five times as high as bankruptcy, after controlling for covariates. Further, while the baseline hazard due to mergers appears to be constant over the post-listing lifetime of a firm, the baseline hazard due to bankruptcy declines with age. This favours learning models. Earlier evidence in favour of such learning models has been advanced from cohort studies of new firms, and it is interesting to observe this for mature firms.

Figures 1 and 3 also plot the year-wise predicted incidence rates of bankruptcies and acquisitions against the observed incidence rates. The close conformity between the two is noteworthy.

6 Left-Truncation and Robustness of Results

As mentioned in Section 3, the duration data is left-truncated. In this section we examine the robustness of our estimates to any dependence between truncation and exits.

As mentioned earlier, the truncation duration L may be represented as $L = \max(L^{**}, 1965 - B)$, where B is the listing-year of the company, and L^{**} represents any delay in entry into our panel, subsequent to listing.[29] The truncation duration L ranges shows considerable variation over the cross-section of firms; the first quartile (Q1), median (Q2) and third quartile (Q3) are 0, 11 and 15 years respectively. A major part of this cross-sectional variation is due to left-truncation of the sample in 1965, since the variation in L^{**} is small relative to L. Since $1965 - B$ is known at the time of listing and is therefore deterministic, L may be independent of the exit duration. The formal test of independence (Tsai, 1990) of the truncation duration L and the (right-censored) exit duration, however, rejects the independence hypothesis for exits due to bankruptcy at 5 per cent level, while it does not reject independence for acquisitions.

If the left-truncation and exit durations are independent conditional on covariates, our model estimates (Table 2) would still be satisfactory; but it is not possible to check for independence of these conditional distributions. We examine robustness by estimating separate hazard models for truncation durations lying within the first quartile, upto the median, and upto the third quartile of the cross-sectional distribution of L. We also truncate the sample at 1970 (instead of 1965), and estimate the models for this sample. If the coefficients are alike in signs and significance we may conclude that our model is robust. These estimates are presented, separately for bankruptcy and acquisitions, in Tables 3A and 3B respectively.[30]

[29]For most companies in our sample, L^{**} is nil, while it may be upto 2 years for a limited number of companies.

[30]Because of low sample sizes in the duration ranges for sub-samples in the lower truncation range, the histogram-sieve estimates in Tables 3A and 3B are based three intervals (0-5 years, 6-15 years, and greater than 15 years) only, as against 4 intervals used in the previous Section.

TABLE 3A: Model Estimates for Bankruptcy, by truncation duration

Variables	**Full sample**	$L \leq 0$ (Q1)	$L \leq 11$ (Q2)	$L \leq 15$ (Q3)	**Trunc. in 1970**
Industry Dummies					
(Base = all others)	1.00	1.00	1.00	1.00	1.00
– Food/Breweries	0.510	0.961	1.319	0.872	0.736
– Chem./Pharma.	1.048	0.839	0.797	0.859	1.229
– Engineering	2.222**	1.694	2.693*	3.132**	3.118**
– Electronics	0.700	0.870	1.158	0.851	0.960
– Textiles	2.891**	4.523**	5.239**	3.997**	3.576**
– Bldg. products	0.407	1.522	1.090	0.669	0.597
– Media	1.915	1.317	2.437	1.628	2.616*
– Construction	3.247**	3.947**	5.581**	4.517**	3.906**
– Trading/Superstores	1.662	2.898*	2.883*	2.550*	2.171*
– Hotels/Entertainment	1.512	2.413^{+}	2.674*	2.069^{+}	1.954^{+}
Firm $\times$ Year Level					
Current size:					
ln(real fixed capital +1)	1.482	1.387	1.338	1.430	1.607^{+}
Size-squared	0.942*	0.944^{+}	0.950^{+}	0.942*	0.934*
Cash flow to Capital = x					
– $x\times$ I(age 0-5 yrs.)	0.909**	0.913**	0.915**	0.911**	0.907**
– $x\times$ I(age 6-15 yrs.)	0.684**	0.680**	0.694**	0.691**	0.684**
– $x\times$ I(age $>$ 15 yrs)	0.325**	0.243	2.062	0.525	0.363**
Return on Capital employed	0.996*	0.997	0.997*	0.997*	0.997*
Macro-Economic Conditions					
Business cycle = y					
– $y\times$ I(age 0-5 yrs.)	11770	18503	31708	32585	9105.3
– $y\times$ I(age 6-15 yrs.)	0.001	0.041	0.012	0.003	0.009
– $y\times$ I(age $>$ 15 yrs)	0.012	2.4e-6	0.009	0.037	0.045
Entries (y-o-y growth rate)	1.012	1.006	1.022*	1.006	1.014
Long-term real interest rate = r					
– $r\times$ I(age 0-5 yrs.)	1.148	1.249^{+}	1.192	1.155	1.135
– $r\times$ I(age 6-15 yrs.)	1.012	1.075	1.031	1.013	0.996
– $r\times$ I(age $>$ 15 yrs)	1.008	1.997	0.996	1.004	0.991
$\pounds - \$$ exchange rate	0.135	0.003**	0.033*	0.106^{+}	0.268

TABLE 3A: Contd.

Variables	Full sample	$L \leq 0$ (Q1)	$L \leq 11$ (Q2)	$L \leq 15$ (Q3)	Trunc. in 1970
MACRO-ECONOMIC INSTABILITY					
Turnaround in Bus. cycle = u					
– $u\times$ I(age 0-5 yrs.)	9.2e-11**	6.0e-10+	8.4e-12**	1.1e-9**	4.1e-10*
– $u\times$ I(age 6-15 yrs.)	0.108	0.003	0.054	0.969	0.257
– $u\times$ I(age $>$ 15 yrs)	9.3e-5	0.002	3.939	0.155	0.004
y-o- y inc.in $£ - \$$ exch.rate = v					
– $v\times$ I(age 0-5 yrs.)	5.1e+5**	9.5e+6**	3.6e+6**	5.5e+5**	6.0e+5**
– $v\times$ I(age 6-15 yrs.)	179.27	24738*	1834.8+	191.45	571.51
– $v\times$ I(age $>$ 15 yrs)	26.155	0.155	11.465	9.597	126.79
Volatility - Retail price index	1.273**	1.386**	1.338**	1.264**	1.294**
Volatility - Long term int. rate	0.973	0.930	1.005	0.977	0.996
Volatility - Short term int. rate	0.965	0.952	0.924+	0.954	0.946
No. of firms	4,320	2,275	2,831	3,438	3,650
No. of exits	166	86	111	137	147
Total time at risk (in years)	45,527	20,220	27,152	34,930	38,766
Log-likelihood	-1094.63	-541.85	-708.23	-884.33	-939.35
Chi- square test stat.(PH assmp.)	32.48	12.86	25.55	31.87	30.38
d.f. / p- value	33 / 0.49	33 / 1.00	33 / 0.82	33 / 0.52	33 / 0.60

Parameters reported are hazard ratios (exponential of the actual parameter values).

Volatility is measured as maximum monthly difference during the year, divided by the number of intervening months (signed).

**, * and + – Significant at 1%, 5% and 10% level respectively.

TABLE 3B: Model Estimates for Acquisitions, by truncation duration

Variables	Full sample	$L \leq 0$ (Q1)	$L \leq 11$ (Q2)	$L \leq 15$ (Q3)	Trunc. in 1970
INDUSTRY DUMMIES					
(Base = all others)	1.00	1.00	1.00	1.00	1.00
– Food/Breweries	1.151	0.831	0.941	1.024	1.074
– Chem./Pharma.	1.174	1.378*	1.279+	1.129	1.147
– Engineering	1.095	1.167	1.156	1.096	1.002
– Electronics	1.448**	1.575**	1.540**	1.495**	1.427**
– Textiles	1.038	0.881	0.881	0.949	0.982
– Bldg. products	1.133	1.027	0.980	1.140	1.059

TABLE 3B: Contd.

Variables	Full sample	$L \leq 0$ (Q1)	$L \leq 11$ (Q2)	$L \leq 15$ (Q3)	Trunc. in 1970
– Media	0.951	1.092	1.094	1.061	0.941
– Construction	0.862	0.843	0.882	0.859	0.809
– Trading/Superstores	1.114	0.981	1.080	1.078	0.984
– Hotels/Entertainment	0.989	1.064	1.020	1.029	0.959
FIRM $\times$ YEAR LEVEL					
Current size:					
ln(real fixed capital +1)	1.409**	1.371**	1.338**	1.403**	1.431**
Size-squared	0.961**	0.970**	0.971**	0.965**	0.961**
Cash flow to Capital $= x$					
– $x\times$ I(age 0-5 yrs.)	4.181**	3.750**	4.078**	4.014**	3.838**
– $x\times$ I(age 6-15 yrs.)	1.302*	1.334**	1.272*	1.278*	1.334**
– $x\times$ I(age $>$ 15 yrs)	0.577**	1.141	0.701	0.604**	0.553**
Return on Capital employed	1.001	1.001	1.001	1.001	1.001
MACRO-ECONOMIC CONDITIONS					
Business cycle $= y$					
– $y\times$ I(age 0-5 yrs.)	68830**	52617**	51614**	56318**	48408**
– $y\times$ I(age 6-15 yrs.)	1711.7**	5098.6**	1018.1**	1369.2**	810.95**
– $y\times$ I(age $>$ 15 yrs)	2.115	1.699	0.657	0.807	0.910
Entries (y-o-y growth rate)	0.997$^+$	1.002	0.997	0.995*	1.002
Long-term real interest rate $= r$					
– $r\times$ I(age 0-5 yrs.)	1.122**	1.107**	1.114**	1.118**	1.100**
– $r\times$ I(age 6-15 yrs.)	0.946**	0.928**	0.940**	0.943**	0.934**
– $r\times$ I(age $>$ 15 yrs)	0.985	1.017	1.000	0.997	0.972$^+$
£ $-$ \$ exchange rate	6.886**	11.468**	8.249**	7.034**	13.796**
MACRO-ECONOMIC INSTABILITY					
Turnaround in Bus. cycle $= u$					
– $u\times$ I(age 0-5 yrs.)	0.017$^+$	0.028	0.035	0.048	0.007$^+$
– $u\times$ I(age 6-15 yrs.)	303.65**	958.75*	396.6**	715.5**	82.894$^+$
– $u\times$ I(age $>$ 15 yrs)	4.018	0.444	1.882	4.190	0.457
y- o-y inc.in £ $-$ \$ exch.rate $= v$					
– $v\times$ I(age 0-5 yrs.)	0.412	0.524	0.409	0.381	0.355
– $v\times$ I(age 6-15 yrs.)	0.321	0.402	0.315	0.297	0.207
– $v\times$ I(age $>$ 15 yrs)	0.170	0.076	0.114	0.144	0.061$^+$

TABLE 3B: Contd.

Variables	Full sample	$L \leq 0$ (Q1)	$L \leq 11$ (Q2)	$L \leq 15$ (Q3)	Trunc. in 1970
Volatility - Retail price index	0.905**	0.947*	0.913**	0.909**	0.930**
Volatility - Long term int. rate	1.030	1.060*	1.052*	1.039+	1.030
Volatility - Short term int. rate	0.992	0.970+	0.991	0.994	0.984
No. of firms	4,320	2,275	2,831	3,438	3,650
No. of exits	1,859	792	1,066	1,383	1,468
Total time at risk (in years)	45,527	20,220	27,152	34,930	38,766
Log-likelihood	-12950.1	-5419.4	-7321.0	-9457.5	-9911.6
Chi- square test stat.(PH assmp.)	14.12	17.46	9.61	11.60	10.90
d.f. / p- value	33 /1.00	33 / 0.99	33 / 1.00	33 / 1.00	33 /1.00

Parameters reported are hazard ratios (exponential of the actual parameter values).

Volatility is measured as maximum monthly difference during the year, divided by the number of intervening months (signed).

**, * and + – Significant at 1%, 5% and 10% level respectively.

Overall, results for the various sub-samples are quite similar to those of the full sample. In other words, in spite of the presence of some degree of unconditional dependence between truncation and exit durations, the estimates are robust.

7 Conclusions

Our objective has been to examine the relationship between business exits and the macro economic cycle, focussing on large and mature (listed) UK companies, over a long (thirty-four year) period. Our aim was to disentangle the joint determination of probabilities of two mutually exclusive processes: firms being acquired and firms going bankrupt. We did this by estimating a competing risks model for the probabilities of exit in either form, in terms of firm and industry characteristics and features of the business cycle. Our model "predicts" the observed time variation in the incidence of bankruptcy and acquisitions very well. The two types of exits are marked by differences in terms of firm-level drivers, industry, macroeconomic conditions and specially, macroeconomic instability.

At the firm level our findings corroborate earlier results. There is some evidence in favour of learning even for mature firms; the baseline hazard due to mergers appears to be constant over the lifetime of a firm, after listing, while that due to bankruptcy declines with age.

Our results relating on the impact of macroeconomic instability on exits are new to the best of our knowledge. There are notable differences in the way in which recently listed firms, and those listed some years previously respond to changes in the macro-economic environment. There is higher propensity of firms that have been listed during the upturn of the business cycle to go bankrupt as soon as the economy turns down. Firms that have weathered the downturn after their listing and in that sense proven themselves "capable", are most likely to be acquired immediately after the economy enters an up phase.

Uncertainty in the form of sharp increases in inflation and sharp depreciation of the Pound affect freshly listed firms adversely. They are more likely to go bankrupt during such years; particularly because acquistion activity is also subdued in such years. These results underscore the importance of smooth macro economic management for the corporate sector.

In terms of econometric method, we used histogram sieve estimators to address the problem of invalidity of the proportional hazards assumption in the duration model. We also assess the robustness of estimates to dependant left-truncation (in a hazard model applied to right-censored duration data).

International comparisons, estimating similar models for other economies would aid understanding and policy. We are currently engaged in estimating a similar model for US to benchmark the above reported results and interpretation.

References

1. Aalen, O.O. (1982). Practical applications of the non-parametric statistical theory for counting processes. Statistical Research Report **82/2**, Institute of Mathematics, University of Oslo.
2. Abowd, J.M., Crépon, B., Kramarz, F. and Trognon, A. (1995). A la recherche des moments perdus: Covariance models for unbalanced panels with endogenous death. Technical Working Paper No. **180**, National Bureau of Economic Research, Cambridge, MA.
3. Agarwal, R. and Gort, M. (1996). The evolution of markets and entry, exit and survival of firms. *Review of Economics and Statistics* **78**, 89–98.
4. Andersen, P.K., Borgan, O., Gill, R.D. and Keiding, N. (1992). *Statistical models based on counting processes.* Springer-Verlag, New York.
5. —— and Gill, R.D. (1982). Cox's regression model for counting processes: A large sample study. *The Annals of Statistics* **10**, 1100–1120.
6. Arjas, E. and Haara, P. (1984). A marked point process approach to censored failure data with complicated covariates. *Scandinavian Journal of Statistics* **11**. 193–209.
7. Audretsch, D.B. (1991). New-firm survival and the technological regime. *Review of Economics and Statistics* **73**, 441–450.
8. —— and Mahmood, T. (1991). The hazard rate of new establishments: A first report. *Economics Letters* **36**. 409–412.
9. —— and Mahmood, T. (1995). New firm survival: New results using a hazard function. *Review of Economics and Statistics* **77**, 97–103.
10. Baldwin, J.R. (1995). *The Dynamics of Industrial Competition: A North American Perspective.* Cambridge University Press: New York.
11. —— and Johnson, J. (1996). Survival of new Canadian manufacturing firms: The importance of financial structure. Working Paper, Micro-Economic Studies and Analysis Division, Statistics Canada.
12. Bhattacharjee, A. and Das, S. (2001). Testing proportionality in duration models with respect to continuous covariates. (Mimeo).
13. Black, J., de Meza, D. and Jeffreys, D. (1996). House price, the supply of collateral and the enterprise economy. *Economic Journal* **106**. 60–75.

14. Boeri, T. and and Bellmann, L. (1995). Post-entry behavior and the cycle: Evidence from Germany. *International Journal of Industrial Organization* **13**. 483–500.
15. Bull, K. and Spiegelhalter, D.J. (1997). Tutorial in biostatistics: Survival analysis in observational studies. *Statistics in Medicine* **16**, 1041–1074.
16. Caballero, R.J. and Hammour, M.L. (1994). The cleansing effect of recessions. *American Economic Review* **84**. 1350–1368.
17. —— and —— (1996). On the timing and efficiency of creative destruction. *Quarterly Journal of Economics* **111**. 805–852.
18. Cabral, L.M.B. (1993). Experience advantages and entry dynamics. *Journal of Economic Theory* **59**. 403–416.
19. Caves, R.E. (1998). Industrial organization and new findings on the turnover and mobility of firms. *Journal of Economic Literature* **36**. 1947–1982.
20. Chadha, J.S., Nolan, C. and Janssen, N. (2000). An examination of UK business cycle fluctuations: 1971-1997. Department of Applied Economics Working Paper **0024**, University of Cambridge.
21. Cnaan, A. and Ryan, L. (1989). Survival analysis in natural history studies of disease. *Statistics in Medicine* **8**, 1255–1268.
22. Cooley, T.F. and Quadrini, V. (1998). Financial markets and firm dynamics. Unpublished Manuscript.
23. —— and —— (1999). Monetary policy and the financial decisions of firms. Preprint.
24. Corres, S. and Ioannides, Y.M. (1996). Endogenous attrition of firms. Working Papers **96-03, 96-04**, Department of Economics, University of Wales, Swansea.
25. Cosh, A.D. and Hughes, A. (1993). The death process: A comparison of large and small company failures and acquisitions. University of Cambridge Small Business Research Centre Working Papers No. **33**.
26. Cox, D.R. (1962). *Renewal Theory.* Methuen: London.
27. —— (1972). Regression models and life tables (with discussion). *Journal of the Royal Statistical Society, Series B* **34**. 187–220.

28. Delli Gatti, D., Gallegati, M., Guilioni, G. and Palestrini, A. (2000). Financial fragility, pattern of firms' entry and exit and aggregate dynamics. Preprint.
29. ——, ——, —— and —— (2001). Financial fragility, heterogenous agents' interaction, and aggregate dynamics. Preprint.
30. Department of Trade and Industry (1989). Insolvencies in England and Wales. *British Business*, July. pp. 22.
31. Desai, M. and Montes, A. (1982). A macroeconomic model of bankruptcies in the British economy, 1945-1980. *British Review of Economic Issues* **4**. 1–14.
32. Disney, R., Haskel, J. and Heden, Y. (2000). Entry, exit and establishment survival in UK manufacturing. Preprint.
33. Doms, M., Dunne, T. and Roberts, M.J. (1995). The role of technology use in the survival and growth of manufacturing plants. *Internation Journal of Industrial Organization* **l3**. 523–545.
34. Dunne, T. and Roberts, M.J. (1991). Variation in producer turnover across US manufacturing industries. in Geroski, P.A. and Schwalbach, J. eds. *Entry and Market Contestability: An international comparison*, Blackwell: Oxford. 187–203.
35. ——, —— and Samuelson, L. (1989). The growth and failure of U.S. manufacturing plants. *Quarterly Journal of Economics* **104**. 671–698.
36. Ericson, R. and Pakes, A. (1992). An alternative theory of firm and industry dynamics. Yale Cowles Foundation Discussion Paper **1041**.
37. —— and —— (1995). Markov-perfect industry dynamics: A framework for empirical work. *Review of Economic Studies* **62**. 53- -82.
38. Evans, D.S. (1987). The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries. *Journal of Industrial Economics* **35**. 567–581.
39. Fazzari, S.M., Hubbard, R.G. and Petersen, B.C. (1988). Financing constraints and corporate investment. *Brookings Papers on Economic Activity* **1**. 141–195.
40. Geroski, P.A. (1991a). *Market Dvnamics and Entry.* Basil Blackwell: Oxford.
41. —— (1991b). Domestic and foreign entry in the United Kingdom: 1983-1984. in Geroski, P.A. and Schwalbach, J. eds. *Entry and Market*

Contestability: An international comparison, Blackwell: Oxford. 63-88.

42. Goudie, A.W. and Meeks, G. (1991). The exchange rate and company failure in a macro-micro model of the UK company sector. *Economic Journal* **101**. 444–457.
43. —— and —— (1992). Forecasting and explaining corporate failure: A study of contingent financial statements. University of Cambridge Discussion Papers in Accounting and Finance No. **AF1**.
44. —— and —— (1998). Company failure and hysteresis. in Begg, I. and Henry, S.G.B. eds. *Applied Economics and Public Policy*, DAE Occasional Papers, vol. **63**, Cambridge University Press: New York. 209–221.
45. Higson, C., Holly, S. and Kattuman, P. (2002 forthcoming). The Cross Sectional Dynamics of the US Business Cycle: 1950-1999. *Journal of Economic Dynamics and Control*.
46. ——, ——, —— and Platis, S. (2001). The Business Cycle, Macroeconomic Shocks and the Cross Section: The Growth of UK Quoted Companies. DAE Working Paper 0114.
47. Gőrg, H. and Strobl, E. (2000). Multinational companies, technology spillovers and firm survival: Evidence from Irish manufacturing. Research Paper No. **2000/12**, Centre for Research on Globalisation and Labour Markets, School of Economics, University of Nottingham.
48. Grambsch, P.M. and Therneau, T.M. (1994). Proportional hazards tests and diagnostics based on weighted residuals. *Biometrika* **81**. 515–526.
49. Grenander, U. (1981). *Abstract Inference*. John Wiley and Sons: New York.
50. Harris, R.I.D. and Hassaszadeh, P. (2000). Exits in UK manufacturing, 1974-1995: Evidence for the motor vehicles industry. Preprint.
51. Han, A. and Hausman, J.A. (1990). Flexible parametric estimation of duration and competing risk models. *Journal of Applied Econometrics*, **5**, 1–28.
52. Heckman, J.J. and Honoré, B.E. (1989). The identifiability of the competing risks model. *Biometrika* **76**. 325–330.

53. Hopenhayn, H.A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica* **60**. 1127–1150.
54. Hosmer, D.W., Jr., and Lemeshow, S. (1999), *Applied Survival Analysis: Regression Modeling of Time to Event Data*. John Wiley and Sons: New York.
55. Hudson, J. (1986). Company liquidations in England and Wales. *Applied Economics* **18**. 219–235.
56. Jovanovic, B. (1982). Selection and the evolution of industry. *Econometrica* **50**. 649–670.
57. Judd, J.P. and Treham, B. (1995). The cyclical behaviour of prices: Interpreting the evidence. *Journal of Money, Credit and Banking* **27**. 789–797.
58. Kalbfleisch, J.D., and Prentice, R.L. (1980). *The Statistical Analysis of Failure Time Data*. John Wiley and Sons: New York.
59. Kattuman, P., Higson, C. and Holly, S. (2000) Mobility, Reversion, Divergence: Evolution of Returns in British Industry. (Mimeo).
60. Keiding, N. (1992). Independent delayed entry. in Klein, J.P. and Goel, P.K. eds. *Survival Analysis: State of the Art*, Kluwer: Dortrecht. 309–326.
61. —— (1997). Delayed entry. in Armitage, P. and Colton, T. eds. *Encyclopedia of Biostatistics* Vol. **2**, John Wiley and Sons: New York. 1120–1125.
62. —— and Gill, R.D. (1990). Random truncation models and Markov processes. it The Annals of Statistics **18**, 582–602.
63. —— and Knuiman, M.W. (1990). Letter to the Editor on 'Survival analysis in natural history studies of disease' by Cnaan, A. and Ryan, L. *Statistics in Medicine* **9**, 1221–1222.
64. Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. *American Economic Review* **86**. 562–583.
65. Lin, D.Y. and Wei, L.J. (1989). The robust inference for the Cox proportional hazards model. *Journal of the American Statistical Association* **84**. 1074–1078.
66. McCall, B.P. (1994). Testing the proportional hazards assumption in the presence of unmeasured heterogeneity. *Journal of Applied Econometrics* **9**. 321–334.

67. Mahmood, T. (1992). Does the hazard rate for new plants vary between low- and high-tech industries?. *Small Business Economics* **4**. 201–209.
68. Martinussen, T., Scheike, T.H. and Skovgaard, Ib M. (2000). Efficient estimation of fixed and time-varying covariate effects in multiplicative intensity models. Paper presented at the 18th Nordic Conference on Mathematical Statistics, Grimstad (Norway), June 2000.
69. Mata, J., Portugal, P. and Guimarães, P. (1995). The survival of new plants: Start-up conditions and post-entry evolution. *International Journal of Industrial Organization* **13**. 459–481.
70. Murphy, S.A. and Sen, P.K. (1991). Time-dependent coefficients in a Cox-type regression model. *Stochastic Processes and their Applications* **39**. 153–180.
71. Nelson, R.R. and Winter, S.G. (1978). Forces generating and limiting concentration under Schumpeterian competition. *Bell Journal of Economics* **9**. 524–548.
72. Pakes, A. and Ericson, R. (1998). Empirical implications of alternative models of firm dynamics. *Journal of Economic Theory* **79**. 1–46.
73. Peel, M.J. (1990). *The Liquidation/ Merger Alternative.* Aldershot: Hong Kong.
74. —— and Wilson, N. (1989). The liquidation/merger alternative: Some results for the UK corporate sector. *Managerial and Decision Economics* **10**. 209–220.
75. Robson, M.T. (1996). Macroeconomic factors in the birth and death of UK firms: Evidence from quarterly VAT registrations. *The Manchester School* **64**. 170–188.
76. Schary, M.A. (1991). The probability of exit. *Rand Journal of Economics* **22**. 339–353.
77. Schoenfeld, D. (1982). Partial residuals for the proportional hazards regression model. *Biometrika* **69**. 239–241.
78. Schwalbach, J. (1991). Entry, exit, concentration, and market contestability. in Geroski, P.A. and Schwalbach, J. eds. *Entry and Market Contestability: An international comparison*, Blackwell: Oxford. 121–142.
79. Siegfried, J.J. and Evans, L.B. (1994). Empirical studies of entry and exit: A survey of the evidence. Review of Industrial Organization **9**. 121–155.

80. Sleuwaegen, L. and Dehandschutter, W. (1991). Entry and exit in Belgian manufacturing. in Geroski, P.A. and Schwalbach, J. eds. *Entry and Market Contestability: An international comparison*, Blackwell: Oxford. 111–120.

81. Tsai, W.-Y. (1990). Testing the assumption of independence of truncation time and failure time. *Biometrika* **77**, 169–177.

82. —— and van Ryzin, J. (1985). Regression analysis with left-truncated and right-censored data. Technical Report, Division of Biostatistics, Department of Statistics, Columbia University.

83. Tsiatis, A. (1975). A nonidentifiability aspect of the problem of competing risks. *Proceedings of the National Academy of Sciences* **72**. 20–22.

84. van den Berg, G.J. (2000). Duration models: Specification, identification, and multiple durations. in Heckman, J.J. and Leamer, E. eds. *Handbook of Econometrics, Volume V*, North Holland: Amsterdam.

85. Wang, M.-C., Jewell, N.P. and Tsai, W.-Y. (1986). Asymptotic properties of the product limit estimate under random truncation. *The Annals of Statistics* **14**, 1597–1605.

86. Wheelock, D.C. and Wilson, P.W. (2000). Why do banks disappear? The determinants of U.S. bank failures and acquisitions. *Review of Economics and Statistics* **82**. 127–138.

87. Winter, J.K. (1999). Does firms' financial status affect plant-level investment and exit decisions?. Preprint.

88. Woodroofe, M. (1985). Estimating a distribution function with truncated data. *The Annals of Statistics* **13**, 163–177. Correction, **15**, 883 (1987).

89. Zucker, D.M. and Karr, A.F. (1990). Nonparametric survival analysis with time-dependent covariate effects: A penalized partial likelihood approach. *Annals of Statistics* **18**. 329–353.

————x————

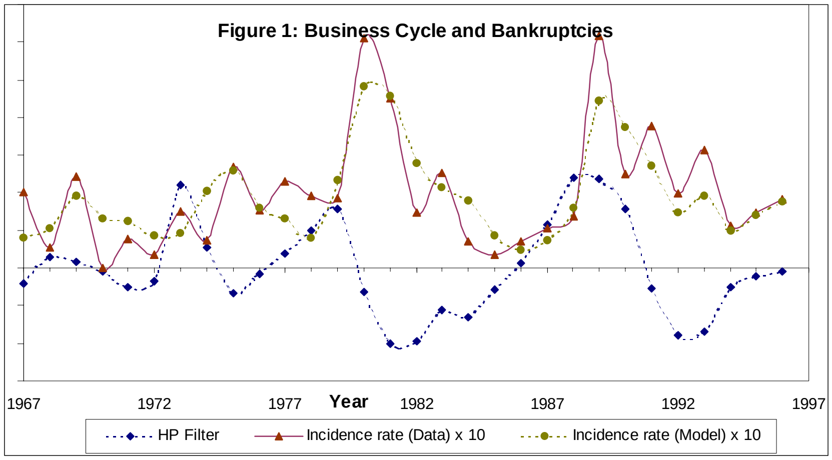

Figure 1:

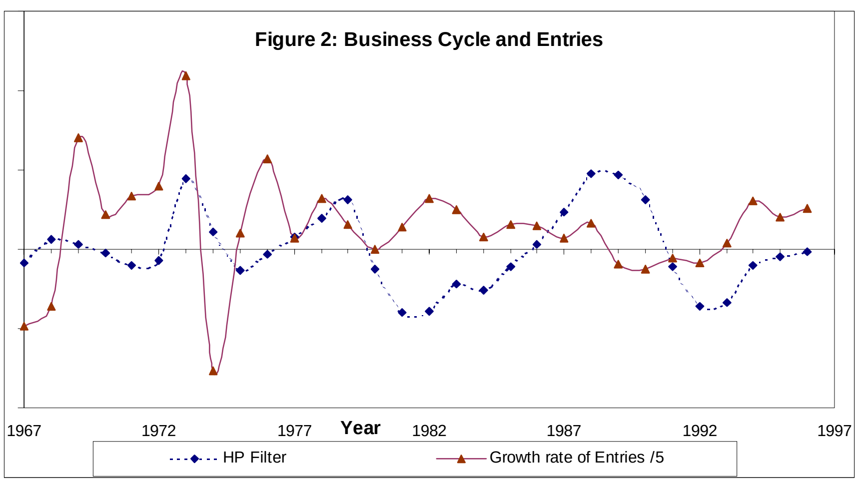

Figure 2:

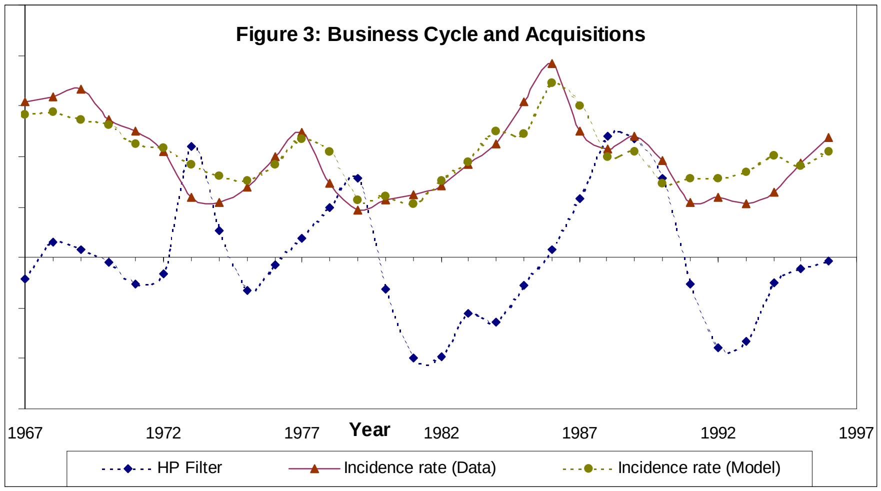

Figure 3:

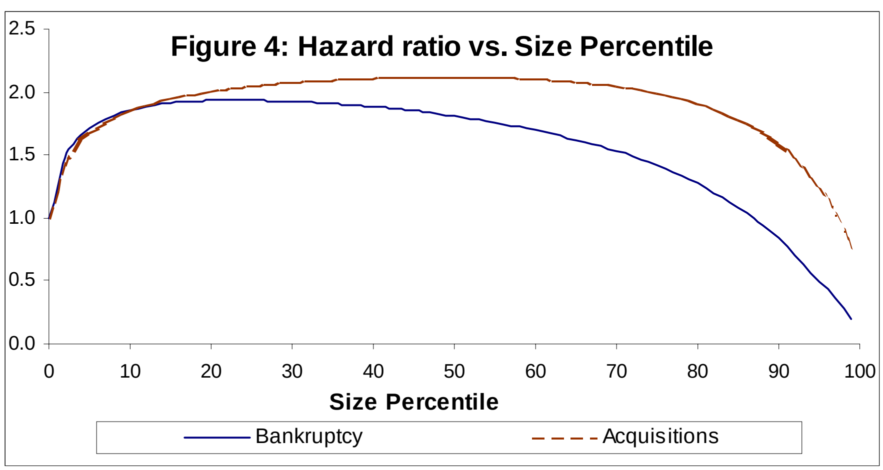

Figure 4:

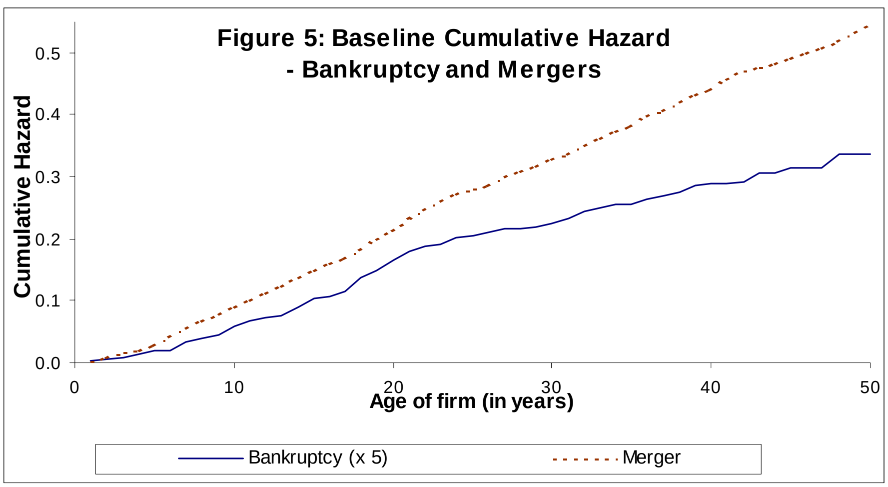
Figure 5: Baseline Cumulative Hazard
- Bankruptcy and Mergers
Cumulative Hazard
0.0
0.1
0.2
0.3
0.4
0.5
0
10
20
30
40
50
Age of firm (in years)
Bankruptcy (x 5)
Merger

Figure 5: